Abstract
In order to meet the special requirements (for the strength and conductivity of concrete structures) that arise during the transmission of electricity to remote areas of the Russian Federation, a variant of using self-healing concrete is proposed. In this material, it is proposed to use microcapsules obtained by the physical method, consisting of sodium silicate and bentonite clay coated with ethyl cellulose with graphene. The mechanism of action of the capsule is as follows: after external mechanical destruction, access to graphene appears and it acts as a conductive medium, resulting in the cementing properties of the capsule core. In the course of the work, the optimal ratio of graphene and the capsule core was established, which was determined during a number of experiments and microstructure studies. The dependences of the compressive strength and conductivity of the composite on the graphene content in the capsule, the number of microcapsules in concrete and the time of strength gain were also revealed. In the experiments, the average size of microcapsules was 1.25 mm, the grain shape is predominantly spherical with a rough surface and dense structure. The optimal microcapsule content was 2.

Index terms—graphene; microcapsules; self-healing cementing materials, compressive strength; conductivity.
Figure 1: Fig. 1:

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Figure 2: Fig. 2:
Figure 3: 2Na 2 ?Fig. 3 :
Figure 4: Fig. 4 :Fig. 5 :Fig. 6 :Fig. 7 :

Figure 5: Fig. 8 :
Figure 6: Fig. 9: Fig. 10:

Figure 7:
Figure 11: ???????? ???????? ???????? . ? ???????? ?? ????? ?? ?????????? ??????? ???????????, ? ????? ????????. ????? ?????????? ??????? ??????? (????????? ??????????) ?? ?????????? ?????????? ???????? ???????????, ?? ??? ??????????? ??????????? ?????????? 81%, ? ?????????? ?????????????? ?????????? ?? ?????? -57%.

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?????? [25], ?. ??? [26] ?? ????? ?????????
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Figure 12: Table 1:
Figure 13:
Efficiency of Self-Healing Cementing Materials

1. ?????????, ??????? 2% ?? ? ? ? ? ?? B 1%: ??? ????????????. 0,05 ?? 0,15%, ?? ????????? ??????????? ?? ???????, ??????????? ?? ????????. ?? ??????????? ?? ?? 0,05 ?? 0,15%, ?? ????????? ?????????? ?????? ????????????.

2. ZHANG Ming. microcapsules and their binary self-healing materials[D]. Harbin Institute of Technology, 2012.)


4. D”???????? ????? ?????? ?????? ?????? ?????? ????? ??????? ?????? ????? ?????? ?????? ?????? ?????? ?????? ?????? ?????? ?????? ?????? ?????? ?????? ?????? ?????? 0,1%; ?? ?? ????? ????? ????? ????? ????? ????? ?????? ?????????? ?? ??????????? ?? ????????? ??????????? ??????????? ?? ????????? ??????????? ?? ????????? ??????????? ??????????? ??????????? ??????????? ??????????? ?????????? ??????????? ??????????? ?????????? ???????????.

5. Figure 14: